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## PATENT SPECIFICATION

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## COMPLETE SPECIFICATION

## NO DRAWINGS

## An Improved Metal Composition and a method of manufacture thereof

We, MALLORY METALLURGICAL PRODUCTS LIMITED, a British Company of 78, Hatton Garden, London, E.C.1 do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement.

This invention relates to an improved metal composition for use in the manufacture of electrodes of the kind employed in resistance welding and electric discharge—or spark-machining, and to a method of manufacture thereof.

One of the major problems involved in present day resistance welding electrode materials is the necessity for frequently re-dressing spot welding tips and seam welding wheels due to deformation thereof at the operating temperature. A need, therefore, exists for an electrode material of improved elevated temperature characteristics for welding applications.

A related problem exists in the case of electrode materials used for electric discharge or spark-machining procedures, in which a metal workpiece is cut by establishing controlled electrical discharges or sparks between an electrode and the workpiece. It has been found that the electrode materials which are most attractive from the standpoint of economical operation are consumed nearly as rapidly as the rate at which the work itself is eroded, so that frequent electrode replacement becomes necessary. A good electrode material for electric discharge or spark-machining must promote spark discharges in order to maintain a high rate of metal removal from the work. At the present time, brass is extensively used for this purpose, owing to the fact that it is relatively inexpensive, is easily machined into unusual shapes, and is cap-

able of giving high cutting rates of up to 0.2 gram per minute on work materials such as cemented tungsten carbide and toolsteel. Unfortunately, the "wear ratio" of brass, or the ratio of the volume of work eroded to the volume of electrode consumed, is only about 1.7. A brass electrode will, therefore, wear out nearly 60% as fast as the rate at which it cuts the work. Much better wear ratios of the order 7 or more may be obtained with electrodes made of high refractory alloys including tungsten or tungsten carbide. These materials, however, are relatively expensive and more difficult to machine, resulting in limitations in the sizes and shapes of the electrodes which can be produced therefrom.

With the aim of overcoming the above difficulties and of providing an improved electrode material possessing good cutting-rate and wear-ratio characteristics, and which, at the same time, could be easily worked, the Applicants conducted experiments with various known materials and found that few materials having comparable or better cutting rates will also provide a good wear ratio. Electrodes made from castings of pure copper and copper alloys were found poor in both respects. However, copper electrodes prepared by powder metallurgy techniques evidenced dependable cutting ability and a wear ratio of about 3. Whilst this is an improvement compared with brass, the Applicants considered that, if the material could be reinforced with an additive, which would reduce the wear without, at the same time, causing reduction in the cutting rate, a much greater improvement could be achieved. It was, moreover, reasoned that, if such an additive could be found, the resulting composition would also possess better high temperature characteristics which should lead to signi-

significantly improved performance in resistance welding applications as well as improved electrical discharge-or spark-machining performance.

5 Further experiments along these lines, led to the discovery that the addition to existing electrode materials of certain metal oxides in prescribed quantity did, in fact, result in a metal composition exhibiting  
10 startling improvements, not only in wear ratio but also in cutting rate, provided certain conditions are adhered to in the manufacture and final structure of the composition.

15 The principal object of this invention therefore, is to provide a metal composition or compact for use in the manufacture of resistance welding or spark-machining electrodes exhibiting improved characteristics compared with existing materials used  
20 for this purpose.

Another object of the invention is to provide a metal composition which may be easily fabricated and machined into any  
25 desired electrode shape and which possesses high resistance to erosion by electrical discharges.

A further object of the invention is to provide a simple and efficient method of  
30 making the improved metal compact by a powder metallurgical procedure.

According to one feature of the invention, therefore, a metal compact for use in the manufacture of resistance welding or spark-  
35 machining electrodes comprises a pressed, sintered and repressed compact of copper, nickel, silver or aluminium metal powder in which is finely dispersed from 0.05% to  
40 30% in total by volume of the composition, of a powdered oxide of zirconium, chromium and/or titanium, the oxide particles being oriented into laminar strata within a matrix of the metallic particles.

A metal oxide content of more than 30%  
45 by volume will render the compact chalk-like and friable. In practice, we prefer to include from 2% to 4% by volume of the oxide additive, optimum results being obtainable by the addition of 3 vol %.

In carrying out the invention in practice, 50 we prefer to use copper as the metal and zirconium oxide as the oxide additive.

According to another feature of the invention, there is provided a method of  
55 making a metal compact for use in the manufacture of resistance welding and spark-machining electrodes which comprises forming a mixture of powdered copper, nickel, silver or aluminium metal and from  
60 0.05% to 30% in total by volume of the mixture of the powdered oxide of zirconium, chromium and/or titanium, heating the mixture in a reducing atmosphere, pressing the heated mixture to form a compact, sintering  
65 the pressed compact and repressing the sintered compact so that the oxide particles become oriented into laminar strata within a matrix of the metallic particles. Preferably, the heated mixture is pressed in a  
70 selected direction to form a compact in which the metal oxide particles are mainly distributed through a lattice of particles of the metal in laminar strata substantially perpendicular to the direction of pressing and the sintered compact repressed in the  
75 same direction.

The average particle size of the metal oxide powder is preferably less than 10 microns FAPS and the milled or otherwise blended mixture should advantageously  
80 have an average particle size within the range of 5 to 10 microns FAPS (Fisher subsieve sizer). The ingredients should be well mixed to obtain uniform dispersion of the oxide prior to pressing, and sintering should  
85 be effected under conditions ensuring effective retention of the oxide in the metallic lattice.

The following Table shows the relative performance of electric discharge-or spark-  
90 machining electrodes made from a sintered and repressed compact of powdered copper containing finely powdered metal oxide dispersed therein in accordance with the invention and produced by powder metallurgical procedures. This data was obtained  
95 with toolsteel as the work material. Brass is included for comparison.

TABLE

100	COMPOSITION (% BY VOL.)	AVERAGE HARDNESS (ROCK- WELL F)	AVERAGE CON- DUCTIVITY (% IACS)	MACHINING RATE (GR./MIN.)	WEAR RATE (VOL. LOSS WORK/VOL. LOSS OF ELECTRODES)
105	Copper 3% ZrO <sub>2</sub>	70	80	0.43	8.2
	Copper 3% TiO <sub>2</sub>	85	83	0.39	6.6
	Copper 3% Cr <sub>2</sub> O <sub>3</sub>	79	76	0.40	6.5
	Brass (free cutting)	90	24	0.21	1.7

110 It is evident from the above tabulation that the preferred electrode material is copper containing zirconium oxide dis-

persed therein.

As will be appreciated from the foregoing, certain critical factors must be ob- 115

served in the manufacture of our improved compositions. One is that, if the powdered metal and the powdered metal oxide additive are mixed by a ball milling or equivalent blending process for an extended period of from 4 to 12 hours, the resulting mixture should be subjected to a reducing condition prior to pressing into a compact in order to eliminate undesired oxides of the metallic ingredient which may have formed. Another significant factor is that the working face of the electrode formed therefrom should lie in a plane substantially perpendicular to the laminar strata in which the metal oxide particles are disposed within the lattice of the metallic particles. This is effected, first, by pressing the initial powdered mixture of metal and metal oxide additive and then, after sintering the resultant compact, repressing it in the same direction. The oxide particles are thus oriented into laminar strata within a matrix of the metallic particles. The repressing operation also serves to stress the metallic particles in that direction. In the manufacture of an electrode, the preform so obtained is maintained to produce the working face of the resultant electrode in a plane substantially perpendicular to the oxide strata. The wear ratio is roughly doubled when the preliminary reduction operation and the described oxide orientation relative to the working face of the electrode are both employed.

In order that the invention may be fully understood, a preferred powder metallurgy process for the manufacture of an electrode in accordance with the invention, will now be described by way of example.

The chosen metal oxide was first powdered to a particular size of less than 10 microns FAPS. This was then blended with powdered copper metal by ball milling for from 4 to 24 hours, depending on when the average particle size of the mixture reached 5 to 10 microns. Undesired oxides of the metallic copper were then eliminated by reduction of the blended powder in an atmosphere of hydrogen or cracked ammonia for about one hour at a temperature of 500° to 700°C. The mixture was then either pressed into a compact at a pressure of between 20 and 30 tons per square inch, the direction of pressing being such as to produce oxide stringers or laminates largely in strata perpendicular to the intended electrode face, or hot extruded to accomplish all the foregoing in a single operation. The compact was sintered at between 1,000°C. and 1,080°C. for 2 to 5 hours, again in a reducing atmosphere of hydrogen or cracked ammonia. The sintered compact was then repressed in the same direction as the original pressing at between 20 and 40 tons per square inch in order to obtain

a final preform density at least 92% of the theoretical maximum, thus helping further to orient the oxide particles in laminar strata and straining the copper grains in the pressed direction. After straining, as described, the preform was machined to a specified electrode configuration with the electrode face in a plane approximately perpendicular to the oxide strata.

We are aware that in Specification No. 917005 which, though not published at the date of this Application, bears an earlier priority date, there is claimed a metallic body produced by working a sintered metallic body consisting mainly of copper and containing a stable insoluble dispersed phase composed of a refractory oxide, which sintered body has been made by a method which includes *inter alia* the step of initially mixing a finely divided powder of the metal with an aqueous solution of a water-soluble salt decomposable by heat to produce a refractory oxide to form a slurry, which is subsequently treated to form a powder mixture of the metal and refractory oxide powders.

We make no claim to such a method of preparation nor to the product of such a method, but, subject to the above disclaimer.

#### WHAT WE CLAIM IS:—

1. A metal compact for use in the manufacture of resistance welding or spark-machining electrodes comprising a pressed, sintered and repressed compact of copper, nickel, silver or aluminium metal powder in which is finely dispersed from 0.05% to 30% in total by volume of the composition, of a powdered oxide of zirconium, chromium and/or titanium, the oxide particles being oriented into laminar strata within a matrix of the metallic particles.
2. A metal compact as claimed in Claim 1 wherein the dispersed metal oxide constitutes from 2 to 4% by volume of the composition.
3. A metal compact as claimed in Claim 2 wherein the dispersed metal oxide constitutes 3% by volume of the composition.
4. A metal compact as claimed in any of the preceding Claims wherein copper metal powder and zirconium oxide powder are used as the constituent materials.
5. A metal compact as claimed in any of Claims 1 to 4 wherein the powdered metal oxide has an average particle size of less than 10 microns FAPS.
6. A metal compact as claimed in Claim 5 wherein the mixture has an average particle size within the range of 5 to 10 microns FAPS.
7. The improved metal compact as claimed in Claim 1 substantially as hereinbefore described.
8. Resistance welding electrodes when

made of, or incorporating, the metal compact as claimed in any of the preceding Claims.

9. Electric discharge-or spark-machining electrodes when made of, or incorporating the metal compact as claimed in any of Claims 1-7.

10. A method of making a metal compact for use in the manufacture of resistance welding and spark-machining electrodes which comprises forming a mixture of powdered copper, nickel, silver or aluminium metal and from 0.05% to 30% in total by volume of the mixture, of the powdered oxide of zirconium, chromium and/or titanium, heating the mixture in a reducing atmosphere, pressing the heated mixture to form a compact, sintering the pressed compact and repressing the sintered compact, so that the oxide particles become oriented into laminar strata within a matrix of the metallic particles.

11. A method as claimed in Claim 10 wherein the heated mixture is pressed in a selected direction to form a compact in which the metal oxide particles are mainly distributed through a lattice of particles of the metal in laminar strata substantially perpendicular to the direction of pressing and the sintered compact repressed in the same direction.

12. A method as claimed in Claim 10 or 11 wherein the metal oxide particles constitute from 2% to 4% by volume of the mixture.

13. A method as claimed in Claim 12, wherein the metal oxide particles constitute 3% by volume of the mixture.

14. A method as claimed in any of Claims 10-13 wherein the mixture is composed of copper metal powder and zirconium oxide powder.

15. A method as claimed in any of Claims 10-14 wherein the powdered metal oxide has an average particle size of less than 10 microns FAPS.

16. A method as claimed in Claim 15 wherein the mixture has an average particle size within the range of 5 to 10 microns FAPS.

17. A method as claimed in any of Claims 11-17 wherein the mixture is heated to 500°-700°C.

18. A method as claimed in Claim 17 wherein the pressed compact is sintered for a period of 2 to 5 hours at a temperature of 1000°C. to 1080°C.

19. A method of making a resistance

welding or spark-machining electrode by powder metallurgy, which comprises the steps of; blending a mixture of at least 96 percent by volume of finely powdered copper, nickel, silver or aluminium metal with at least 2 percent by volume of the finely powdered oxide or zirconium, chromium or titanium until the average particle size of the blended mixture lies in the range from 5 to 10 microns FAPS; heating said mixture in a reducing atmosphere at a temperature in the range from 500°C. to 700°C; pressing said mixture in a selected direction to form a compact in which the particles of said metal oxide are largely distributed in a lattice of the metallic particles in laminar strata substantially perpendicular to said direction; sintering said compact in a reducing atmosphere for a period of from 2 to 5 hours at a temperature in the range of from 1,000°C. to 1,080°C; repressing said sintered compact in said selected direction to a density of at least 92 percent of the maximum theoretical value, thereby producing an electrode preform in which said metallic particles are significantly strained in that direction and said metal oxide particles are further oriented in laminar strata perpendicular thereto; and machining said preform to form an electrode, the operating face of which lies in a plane approximately perpendicular to the metal oxide strata.

20. The improved method of making a metal compact for use in the manufacture of resistance welding and spark-machining electrodes substantially as hereinbefore described.

21. Resistance welding electrodes when composed of, or incorporating a metal impact made by the method claimed in any of Claims 10-18 or in Claim 20.

22. Resistance welding electrodes when made by the method claimed in Claim 19.

23. Electric discharge-or spark-machining electrodes when composed of, or incorporating, a metal compact made by the method claimed in any of Claims 10-18 or in Claim 20.

24. Electric discharge-or spark-machining electrodes, when made by the method claimed in Claim 19.

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